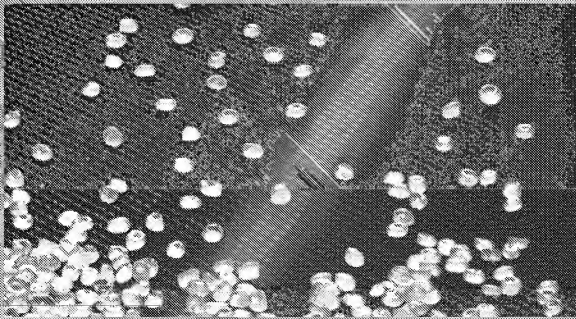


MASTERBATCHES



## Melt Flow Index



# Melt Flow Index



One of the properties most often quoted for both natural polymers and masterbatches is Melt Flow Index (MFI).

## What is MFI and why is it significant ?

Melt Flow Index is the output rate (flow) in grammes that occurs in 10 minutes through a standard die of  $2.0955 \pm 0.0051$  mm diameter and  $8.000 \pm 0.025$  mm in length when a fixed pressure is applied to the melt via a piston and a load of total mass of 2.16 kg at a temperature of  $190^{\circ}\text{C}$  (some polymers are measured at a higher temperature, some use different weights and some even different orifice sizes).

Melt Flow Index is an assessment of average molecular mass and is an inverse measure of the melt viscosity; in other words, the higher a MFI, the more polymer flows under test conditions. Knowing the MFI of a polymer is vital to anticipating and controlling its processing. Generally, higher MFI polymers are used in injection moulding, and lower MFI polymers are used with blow moulding or extrusion processes.

## What affects the melt flow properties of polymers ?

Many factors affect polymers' flow properties. Molecular weight distribution, the presence of co-monomers, the degree of chain branching and crystallinity influence a polymer's MFI as well as heat transfer in polymer processing.

## How is MFI important to masterbatches ?

In addition to its importance to natural polymers, the MFI of a masterbatch is also important because the MFI indicates the relative ease with which a masterbatch can be distributed during a compounding operation or in injection moulding machines, film extruders, etc.

**Though all fillers and additives influence the flow properties of masterbatches, which ones have the greatest effect ?**



Carbon blacks have the most pronounced effect, and unless very high flow polymers are used as carriers, resultant masterbatches have little or no flow when measured using a standard 2.16 kg weight. For this reason most data sheets quote values measured using higher weights (e.g. 21.6 kg). For example, a typical masterbatch containing 40% carbon black in LDPE could have the following flow rates all measured at 190°C:

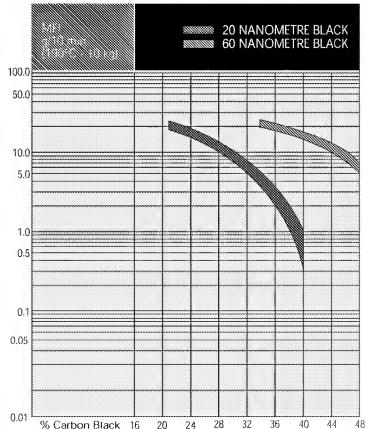
Test weight (kg)	MFI (g/10 min.)
21.6	150
2.16	< 1

The main parameters of carbon blacks that influence the MFI are the particle size, structure and surface chemistry. Melt viscosity of polymer carbon black mixtures increases as the carbon black content increases and also the particle size of the black decreases. Narrow carbon black particle size distribution also leads to higher viscosity; this reinforcing characteristic of carbon blacks limits the practical levels at which they can be incorporated into thermoplastic polymers. Although there are some exceptions, 50% is widely accepted as the upper limit for 60 nanometre particle size carbon blacks incorporation with resin and 40% for 20 nanometre blacks.



Effects of particle size on flow over a range of carbon black loadings is shown, as an example, in the following graph:

**Flow Properties of Masterbatches of Carbon Black in Melt Index 2.0 Low Density Polyethylene**



### **How does someone choose a masterbatch for a specific use ?**

The ideal choice of a masterbatch for a specific end use is one that matches the MFI of the masterbatch as closely as possible with the MFI of the base resin.

This is reasonably easy to do with titanium dioxide-based (white) masterbatches and some additive masterbatches, but not as simple with black masterbatch because of the reinforcing nature described above.

If the masterbatch is to be compounded into the base polymer using, for example, high shear mixing equipment, an internal mixer or twin screw extruder, it is possible to choose a fairly low MFI carrier resin and still achieve excellent incorporation. Polymer producers generally follow this practice when making pipe or cable compounds in order not to affect the final performance properties of the compound.

If poor distribution occurs when simultaneously feeding masterbatch and resin into an injection moulding or extrusion process where the shear forces are somewhat lower, the processor can adjust equipment operation conditions (such as increased back pressure, use of turbine mixing heads, or cavity transfer mixers at the end of the extruder screw). To maintain output rates, usually the processor specifies a masterbatch that is compatible with the base resin and the operating conditions.

If necessary, adjustments to increase the MFI of black masterbatches are possible.

Three suggestions are to use:

- a higher flow carrier resin;
- a less reinforcing grade of carbon black; or
- process aids (e.g. stearates).

If none of these are acceptable, then reducing the carbon black content in the masterbatch may be the only answer (for example use a 25% or 30% masterbatch instead of a 40% or 50%).

When combinations of masterbatches are used, the high flow nature of one can adversely affect the proper incorporation of the other. In the manufacture of tackified silage film, for instance, some manufacturers add a PIB masterbatch (PIB = polyisobutylene) and black masterbatch simultaneously. If distribution problems occur because the PIB reduces the shear in the system, the black masterbatch must be respecified.



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Titanium dioxide-based masterbatches (white), inert filler masterbatches, and additive masterbatches (for example, UV stabilisers) affect processing differently than carbon black masterbatches. Because materials like titanium dioxide and calcium carbonate do not have a significant reinforcing effect on resins, meaningful MFI values using a 2.16 kg weight can be measured, and much closer matching of masterbatch and base resin in MFI is possible even with loadings as high as 80%. Take, for example, a 75% titanium dioxide pigment masterbatch incorporating an LDPE carrier of melt index 20 gr/10 min. This masterbatch would have a melt index somewhere around 4 gr/10 min (2.16 Kg/190°C), which is similar to a melt index of 2 gr/10 min. (LDPE film grade commonly used by processors). Thus, the masterbatch and diluent polymers melt indices are broadly equivalent.

Many of the additives used in additive masterbatches are low melting point materials (UV stabilisers, slip agents such as oleamides or erucamides, or antistatic agents) and can melt before the carrier resin causing difficulties for the masterbatch producer and significantly increasing the effective MFI of the masterbatch.

MFI is vital knowledge for polymer processing. If you want to find out more about MFI, you can refer to the following references:

- ASTM Standard D1238 "Standard Test Method for Flow Ratios of Thermoplastics by Extrusion Plastometer"
- ISO1133 "Plastics - Determination of the Melt Mass-Flow Rate (MFR) and Melt Volume-Flow Rate (MVR) of Thermoplastics".

In addition, your Cabot representative can assist you with recommendations of Cabot masterbatches to meet your requirements.



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